1968

A method to evaluate investment projects in underdeveloped countries.

Vick, Gerald Allen

Monterey, California. Naval Postgraduate School

A METHOD TO EVALUATE INVESTMENT PROJECTS IN UNDER-DEVELOPED COUNTRIES

GERALD ALLEN VICK

A METHOD TO EVALUATE INVESTMENT PROJECTS

IN UNDERDEVELOPED COUNTRIES

by

Gerald Allen Vick
Major, United States Army
B.S., United States Military Academy, 1961

[redacted]

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
June 1968

ABSTRACT

The evaluation of proposed projects for changes in the transportation networks of underdeveloped countries is examined by using a benefit-cost method of analysis. The benefits of investment projects are evaluated through the use of a linear program model which minimizes the cost of production for critical commodity goals. The constraints for the linear program are obtained through the use of input-output systems and multi-regional programming. A present value formulation is used to compare the results of a least investment sequence to all other feasible sequences. The use of the procedure recommended results in the identification of a feasible investment sequence which will result in the achievement of the required production goals. The results of the procedure can be explained in physical terms to identify the reasons for the differences in the resulting present value of the various investment sequences.

Thesis by: Gerald A. Vick, entitled "A Method to Evaluate Investment Projects in Undeveloped Countries."

ERRATA

Page	Line	change	to
2	1/2	transport-ation	transpor-tation
8	middle pg.	signi-ficant	signifi-cant
10	2	dilema	dilemma
10	middle pg.	signi-ficant	signifi-cant
13	lower	pro-duct	prod-uct
14	middle	criteria	criterion
16	lower	occuring	occurring
19	4/5	signi-ficant	signifi-cant
22	3&4	tradition-all	tradition-ally
22	14	criteria	criterion
23	3	criteria	criterion
23	13;15;23	criteria	criterion
24	11; 13	criteria	criterion
30	16; 17	shipped -- cannot be hyphenated	
37	6	"if to "in" to read: "shown in Figure 3"	
37	middle pg.	para-meters	param-eters
38	7	values is	values are
43	7	minimum	maximum
43	lower pg	consider-ed	consid-ered
49	middle pg	program-med	pro-grammed.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The underdeveloped countries are attempting to increase the standard of living for their populations in the minimum amount of time. In order to obtain the efficient use of their limited resources, a method of evaluating proposed investment projects is an essential requirement. Methods which have been used in economies which are considered developed are not necessarily applicable to an underdeveloped economy. The underdeveloped countries are faced with accomplishing changes in their economies in a very short period of time. Methods which depend on trial and error, duplication of effort, or inefficient use of limited resources must be avoided if the standard of living within the underdeveloped countries is to be increased.

The term underdeveloped will be used to describe a country which is relatively poor in contrast to countries which are considered developed. The application of the term is arbitrary and is subject to argumentation in individual cases. Examples of underdeveloped countries are; Bolivia, India, Kenya, Peru, South Korea, and Thailand. Examples of developed countries are Belgium, Canada, the United Kingdom, and the United States.[1]

The situation existing in most of the underdeveloped countries is one which requires the expenditures of large amounts of money to create conditions where the resources of the countries and the population can be used efficiently in producing the necessities of a higher standard of

---

[1]Walter Krause, Economic Development (San Francisco: Wadsworth Publishing Company, Inc., 1961), p. 16.

living. The opportunities for investments far exceed the resources immediately available. This requires that expenditures by the countries be carefully evaluated to obtain the best results.

The evaluation of investments in the transport sectors of underdeveloped countries is one of the problems inherent in their economic development. The transportation system within a country has an important effect on every sector of economic development. Mr. Wilfred Owen in Strategy for Mobility emphasized the importance of the transport sector in economic and social development.

> Transport is a necessary ingredient of nearly every aspect of economic and social development. It plays a key role in getting land into production, in marketing agricultural commodities, and in making forest and mineral wealth accessible. It is a significant factor in the development of industry, and in the expansion of trade, in the conduct of health and education programs, and in the exchange of ideas.
>
> . . . .
>
> Transport difficulties have their political and social as well as their economic impacts. Poor transport makes it exceedingly difficult to achieve national unity. The growth process is retarded by limited opportunity for public officials to travel through their country and by difficulties of conducting business. Poor transport can be a major obstacle to maintaining internal security. It also limits the effectiveness of technical assistance programs.[2]

If the underdeveloped country is attempting to create an industrial base for the manufacture of consumer goods, it is often faced with the lack of sufficiently large markets within the country caused by the inadequate transportation network within the economy.

---

[2]Wilfred Owen, Strategy for Mobility (Washington: Brookings Institution, 1965), pp. 1-7.

> In fact producers frequently are deprived of even the stimulus that might stem from the sales potential in an integrated, though small, national market, since poor or costly transport facilities act to confine market exploitation mostly to areas where production occurs. Similarly, the sale abroad of raw materials, encompassing food stuffs and other raw materials is ordinarily hampered by time, cost and some other considerations involved in reaching markets, as well as by conditions of inelastic demand that customarily confront the products.[3]

The underdeveloped countries have recognized the importance of improving their transportation networks and have planned expenditures of from ten to sixty-three per cent of their public expenditures on transport and communication investments. Examples of the per cent of total public expenditures for different planning periods ranging from 1956 to 1961 are; Malaya (22.3%), India (28.8%), Pakistan (17.8%), Thailand (42.2%), and South Vietnam (37.4%).[4] The expenditures on the transport sector are large in most of the underdeveloped countries and require a significant portion of their available resources.

Several countries have used the transport area as the key sector for investments. This has resulted in a poorly balanced development program in some of the countries. Columbia invested approximately 63% of its government expenditures in transport and communication for an extended period. This resulted in serious deficiencies in education and other services.[5] The danger of attempting to use the transportation sector as the only area for government investment was clearly

---

[3]Krause, _op. cit._, p. 66.

[4]Owen, _op. cit._, p. 45.

[5]_Ibid._, p. 40.

identified by Mr. Owen;

> This is the dilema, then, that is posed by the big push in transport. Construction and maintenance of transport facilities have to be sufficient to assure the capacity to meet growing traffic requirements. At the same time, transport developments are so costly that their claim on a country's limited resources should be weighed with an awareness of other vital requirements that might yield a greater return in better living.[6]

Since the transport sector is involved in nearly every aspect of economic development, the evaluation of transport projects must consider the goals, resources, and development plan of the individual country. Although the goals and problems of different underdeveloped countries may be similar in many aspects, the national goals, cultural background, and geographic aspects of each country will creat significant differences in the plans for development of their transportation networks. The transport projects of an underdeveloped country must be evaluated as to their ability to support the overall economic development plan. The problem must be viewed as a total systems problem with the transport sector being a subsystem of the overall economy.

It is the objective of this thesis to examine methods of evaluating investments within the transport sector and to develop a method which can be used to evaluate specific proposals within individual underdeveloped countries. Chapter II, Economic Development Planning, will discuss what economic development planning is and what guidelines it provides for the evaluation of proposed investment projects. Chapter III, Benefits of the Transportation Network, will discuss the benefits provided by investments in the transportation sector of the

---

[6] Ibid., p. 41.

economy. Chapter IV, Methods to Measure Benefits From Investments, will discuss the existing methods which are used to determine the value of investments in transport projects. Chapter V, Input-Output Systems and Multi-Regional Programming, will discuss a model which has been proposed for evaluating the effect of changes in the transportation network. Chapter VI, Procedure For Evaluating Investment Projects will discuss the application of the model to programming investments and will recommend an overall procedure to be used. Chapter VII, Recommendations and Conclusions, will discuss the overall results of the proposed method and further areas of study in investment programming of transportation projects.

CHAPTER II

ECONOMIC DEVELOPMENT PLANNING

Economic development planning is the overall approach that the underdeveloped country uses in deciding what direction they will pursue in their economic development. Each country will have a different economic development plan. A general procedure that is used has been presented by Chenery and Clark and would include;

> The more complete development programs include the following features.
>
> (i) A statement of objectives of national policy, the most common of which are increasing national income, reducing unemployment, maintaining or achieving balance in international trade, and improving the distribution of income.
>
> (ii) Projections of the growth of national income, consumption, investment and balance of payments.
>
> (iii) Estimation of the supply of domestic savings, foreign investment, various categories of labor, and other resources.
>
> (iv) A statement of criteria for the allocation of investment funds and foreign exchange subject to government influence in the light of their aggregate supply and demand and of the national objectives.
>
> (v) Projection of the growth of various sectors of the economy and the needs of each sector for investment funds and other resources.
>
> (vi) A balancing of resource needs from (v) against availabilities from (iii) and a reconciliation of sector and aggregate projections.[7]

The procedure outlined above indicates that some of the long term planning which is conducted by the private sector in many of the advanced economies will be conducted by the government in the underdeveloped countries. In order to effectively use their scarce resources, the underdeveloped countries should be approaching the economic development from a total systems approach. If each of the

---

[7]Hollis B. Chenery and Paul G. Clark, Interindustry Economics (New York: John Wiley and Sons, Inc., 1964), p. 281.

subsectors of the economic system was independent, the subsectors could be investigated individually. However, the transport sector provides services to the other sectors of the economy and cannot be considered separately from them. If the transport sector was examined as a separate portion of the economy and an effort was made to maximize benefits within the transport sector without considering its effects on other parts of the economy, there would not be any reason to believe that this would result in the optimal set of investments to support the overall economic development plan.

The objectives of the development plan must be clearly stated. The economic and noneconomic objectives of the underdeveloped country must be clearly identified to facilitate the selection of criteria for investment projects.

The method of causing economic improvement will vary according to the country's problems. Chenery and Clark indicated three of the basic approaches;

> (i) The first approach, which is derived from classical principles of economics, is to try to maximize the national product by equating the marginal productivity of investment or other resources in different uses. Although this test is commonly referred to, it is not widely used because of the difficulty of measuring the marginal product attributable to a given factor in a given use.
>
> (ii) The second and commonest method, which may be called the scarce factor approach, is derived from the existence of structural disequilibrium. It tries to allow for the defects in the price system by giving priority to projects which economize on scarce factors, such as foreign exchange or investment funds, or alternatively to those which use large amounts of the abundant factors, labor and local resources. . . .

> (iii) The third approach to the selection of priority sectors ignores the short-run calculations based on increases in production and cost and concentrates on the selection of "key sectors" which will contribute to a balanced pattern of growth in the long run. . . .[8]

Regardless of the approach that is selected by the underdeveloped country, the development plan will identify certain commodities which are the important factors in the economy. It will estimate goals for production of those commodities for various points in time in the future. The commodities which are selected as important are those which will generally require additional production facilities, changes in the transportation network, and technological improvements to achieve the programmed goals.

One criteria which is required for the evaluation of investments is the discount rate that is to be used in any evaluation of benefits and costs associated with an investment project. This can be expected to vary from country to country and will not be discussed in this paper. It will be assumed that the overall development plan will provide the discount rate.

Investments in the economic sectors will have an effect on the noneconomic goals of the development plan. The overall importance of the economic and noneconomic objectives enumerated in the development plan will have an important effect on the final selection of investments in the economic sectors.

In summary, it has been assumed that the economic development plan will specify the importance of each of the different types of goals, the production goals for the critical commodities and a

---

[8] Ibid., p. 282.

discount rate which is to be used in economic evaluations. The following chapter will discuss the benefits which are created by investments in the transportation sector of an underdeveloped country.

CHAPTER III

THE BENEFITS OF THE TRANSPORTATION NETWORK

The benefits of the transportation network are found throughout the structure of the economy of the underdeveloped country. A change in the transportation network can have significant effects on the economic and noneconomic goals of the country. This chapter will discuss the benefits of the transportation network which should be considered when investment projects are evaluated.

The benefits fall into two primary categories, benefits which are primarily of an economic nature and benefits that are noneconomic in nature.

The economic benefits can be broken into two categories, the direct and indirect benefits caused by a change in the transportation network. The direct economic benefits will be defined as those benefits which occur directly because of the network change and are evident in the immediate area of the change. The indirect economic benefits are those which occur as a result of the network change but which are not necessarily in the immediate area of the change in the transportation network.

The most evident direct benefit is the decrease in the transportation costs for the existing level of shipments occuring on the portion of the network which is changed. The existing volume of goods transported on that portion of the network times the decrease in cost will be a benefit that accrues to either the entrepreneur or to the consumer in either larger profits or in a reduced cost.

The increased production resulting from the use of previously underdeveloped agricultural areas or mineral deposits is a direct benefit of the penetration road or railroad which makes the previously inaccessible area available for development. The increase in value of the minerals or agricultural goods minus the cost of production can be considered a benefit that resulted from the change in the transportation network which made the area accessible.

The indirect economic benefits are benefits which cannot be easily evaluated as a direct benefit of the change in the network. These benefits often occur over a long period of time and can result at a location a considerable distance from the change in the transportation network.

One of the conditions of an underdeveloped country is that it generally does not have markets which are large enough to provide the demand for goods that is necessary to support large scale industry within the underdeveloped country. This usually means that the markets are primarily local markets where the efficiency of mass production techniques can not be applied. The changes in the transportation network can create larger markets which will enable the application of mass production techniques.

The underdeveloped countries are often using their resources in an uneconomic manner. Because of the high cost of transportation associated with an inadequate transportation network, production occurs in local areas using materials which may not yield the best results but which are used because of the high cost of linking the desired raw material with the production capability. The changes in

the transportation network which result in lower transportation costs will allow the market to use the materials where their marginal return is the largest. The high transportation costs which cause inefficient use of the factors of production within an underdeveloped country can be reduced by changes in the transportation network.

The changes in the transportation network which result in lower shipment costs and less delay in moving products to market can create induced production. In many of the underdeveloped countries it is cheaper to import some commodities from other countries than it is to produce the commodity and then to ship the internally produced commodities on the high cost transportation network. If the cost of transporting the commodities is reduced, the internally produced commodity can become competitive in the markets. This will induce producers to manufacture more since they can now market their increased production. This could result in a decrease in imports and an increase in commodities available for export. This can have an important effect on the availability of foreign exchange for desired investments in new production facilities or other development programs.

The changes in the transportation network which result in less time for shipment of goods can result in significant reductions in inventories which must be maintained by producers. This increases the funds which are available for other uses and decreases the resources which were previously tied up in transit or in storage. The shorter length of time that the commodities are in transit will reduce losses due to spoilage and theft.

A benefit which is often considered in developed countries is the increased value of the land which resulted from a transportation network change which made the land more accessible. This benefit will not be considered as significant for underdeveloped countries. It is a significant consideration in discussing the benefits of transportation network changes in developed countries.

Many of the evaluations of road projects within the United States calculate the number of commuter hours saved by a road project, assign an arbitrary dollar value to an average commuter's time, and include the resultant dollar value of the saved commuter hours as an economic benefit in the overall evaluation. For an underdeveloped country, the saving in commuter time is unlikely to be considered an important economic benefit.

The primary economic benefits resulting from transportation network changes are the resulting use of the factors of production in an efficient manner and the reduced cost of production.

The noneconomic benefits are important in an underdeveloped country. The country will often have the goal of increasing the stability of the government to induce local and foreign investments. When the government is unstable, investments are difficult to generate. An efficient road network can enable the government officials to move around the country and will tend to increase the unity of the country. The governments presence will be more noticeable due to the more frequent visits of government officials and the population will tend to identify with the government.

Changes in the network can result in benefits of greater military security. An efficient transportation network can enable

the country to maintain a greater level of security with its military forces or to maintain the existing level of security with smaller military requirements. The increased ability of the military forces and the police to move around the country will aid in providing government stability.

The development goals of many countries include providing increased health, education, and government services to the population. Many of the countries have found that improved transportation facilities have enabled them to provide these services to areas previously inaccessible. Mobile teams of medical personnel, teachers, and government officials, have been used to extend these services to larger areas within the underdeveloped countries.

The benefits which have been discussed above are not considered an exhaustive list of benefits that result from changes in the transportation network of an underdeveloped country. The examples of benefits that have been included indicate the difficulty of obtaining a single measure for evaluating all benefits. Social benefits, such as increased health service, are difficult to measure as dollar values. To include social benefits as estimates in the evaluation process, could result in confusing rather than illuminating the economic benefits of an investment project. Mr. Robert Dorfman discussed this problem in the introduction to Measuring Benefits of Government Investments.

> They agreed that many important aspects of a public investment project are not amenable to quantitative appraisal in the light of objective standards. In fact, at present this is painfully true, since benefit-cost analysis is a largely undeveloped art except in the context of water resource development, but even if one takes the most hopeful view of the future, some significant consequences of public undertaking

> must, it seems, always elude the craft of the quantifier. Nevertheless, the process of political decision can be sharpened significantly by removing as many aspects as possible from the realm of unsupported opinion and emotive rhetoric. In the field of water resources, public decisions have been noticeably more rational and consistent through submitting all project proposals to the discipline of comparing measurable costs with measureable benefits. At the very least, such a process enables attention to be focused on the question of whether the unmeasurable benefits are deemed impressive enough to justify sustaining the measureable costs that they entail.[9]

The objective of the remainder of this thesis will be to develop a method which will provide a means to estimate the economic benefits of investments. The next chapter will discuss the methods which have been used for the evaluation of investment projects and will consider these methods for use with underdeveloped countries.

---

[9] Robert Dorfman, _Measuring Benefits of Government Investments_ (Washington, Brookings Institution, 1963), p. 2.

CHAPTER IV

METHODS TO EVALUATE INVESTMENTS

In whatever process is used to select the investments that will be made in the economy of an underdeveloped country, a method of evaluating the various investments opportunities will be required. Tradition-all, there are four basic methods of evaluating investment opportunities that are discussed in economics textbooks. Three of these, the payback, internal rate of return, and discounted present value are discussed in detail in William J. Baumol's text, Economic Theory and Operations Analysis.[10] The fourth method which is commonly used in government investment projects in the United States is the benefit-cost ratio. A complete discussion of how this method is applied in the United States is contained in Otto Eckstein's Water-Resource Development.[11] Each of these four methods will be discussed briefly as to its use for evaluation of projects in underdeveloped countries.

The payback criteria is used to select investment projects where the return will pay back the investment in the shortest period. If a project costs one hundred dollars in investment and will return fifty dollars a year, it has a payback period of 2 years. A second project which costs three hundred dollars in investments and returns seventy-five dollars a year would have a payback period of four years. The payback criteria would indicate that the first project would be

---

[10] William J. Baumol, Economic Theory and Operations Research (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1961), pp. 434-447.

[11] Otto Eckstein, Water-Resource Development(Cambridge: Harvard University Press, 1965), pp. 47-109.

funded before the second project. The weakness of this criteria is that the first project could result in no benefits beyond the second year while the second project might yield a return for twenty years. The criteria is not acceptable for use in determining investments in an underdeveloped country because it only considers the limited time period required to regain the initial investment.

The remaining three methods are all types of benefit-cost analysis. Each of the methods requires the identification of the time stream of benefits and costs associated with a project.

The internal rate of return method is an evaluation of the rate of interest or the return that the expected future marginal returns will yield to make the discounted value of the expected returns equal to the initial investment. The criteria to invest in a project is to select any project which results in a rate of return which is greater than the interest rate of money in the economy. The criteria is not effective when it is used to select combinations of projects within a fixed budget. It cannot be applied to all government projects since some of the projects will not yield the interest rate which is received by the private sector of the economy, but which do provide an essential service for the economy as a whole.

The discounted present value method is applied by discounting the timestream of the differences between costs and benefits for each year at the applicable discount rate. The criteria is to fund any project that results in a positive present value. This method cannot be used to compare projects with different magnitudes of required investments. The method might merely result in the selection of the

largest projects since it only provides the magnitude of the value of the discounted difference and does not consider the relative size of investments required. Since it does not discriminate between the relative value of two investment projects, it cannot be used by itself as an effective means of comparing investment projects in an underdeveloped country.

The fourth method, the benefit-cost ratio, is used in several different ways. The basic method is to compare the total return of the benefits to the total cost. Sometimes the ratio is used with average return in the numerator and the average cost in the denominator. The ratio can be used by placing the discounted present value of the costs in the denominator. The criteria is to select those projects which have a benefit-cost ratio greater than one. Mr. Otto Eckstein has indicated that the primary use of the benefit-cost criteria in the water resource area has been to obtain economic justification for a project rather than as a means to compare investment opportunities.

> The Flood Control Act of 1936 requires that benefits must exceed costs, "to whomsoever they may accrue," for projects to be authorized. This legal requirement has molded the development of the benefit-cost analysis. Project reports present the results in such a way that they stress the legal economic justification, that the benefits do exceed the costs. Once this test is passed, all projects are on the same footing, and only the agency's judgment based on political circumstances internal and external to the agency, need determine the choice of projects to be submitted for inclusion in the budget.[12]

The actual use of the size of the benefit-cost ratio as a discriminating factor has been very limited in actual practice. It is a method which could be used to compare projects within a limited

---

[12] Ibid., p. 47.

budget constraint situation. The major problem in its use is to define what benefits will be credited to an individual project when the method is used.

The evaluation of investments in an underdeveloped country must consider the order in which projects are accomplished.[13] In an underdeveloped country, a proposed project might be to increase the capacity of production of a commodity at a location which has the lowest marginal cost in terms of required inputs. A second project might be to reduce the cost of transportation on a portion of the transportation network for an area which is producing the same commodity at a higher marginal cost, but where the total production capability is not in use. If the first project is funded before the second project and eliminates the demand for the commodity to be produced at the second location, the benefit created by the road improvements to the second location would be zero. If the first project is not funded, the benefit that is created by the improved road is the reduced cost of transportation of the existing shipments plus some portion of the value of the induced production which may occur at location two now that the overall cost of production plus shipment costs has been reduced. The method that is to be used for underdeveloped countries must allow the different sequences of investments to be considered when the benefits derived from the investments are evaluated.

In an underdeveloped country, changes in the transportation network have important secondary effects on where production will occur. If the transportation cost reduces the overall cost of a commodity, it

---

[13]Ibid., p. 32.

could result in using existing production facilities which are not producing at the lowest marginal cost in preference to facilities which exist in another area which do produce at the lowest marginal cost. This means that if a transportation project is evaluated without regarding the changes that are occuring in planned investments in increased production capability or in technological improvements, the benefits that are being credited to the project might not exist under the new situation created by the investments in increased production capability or improved technological methods in other areas. The method which is used for evaluation of investments in underdeveloped countries should allow the interaction between the investments in increased production capability, improved technology and changes in the transportation network to be considered to evaluate what the optimal mix of investments should be.

A method which has been presented by Mr. Mitchell Harwitz suggests the use of input-output systems and multi-regional programming to measure the effects of highway investments. The model proposed by Mr. Harwitz, a linear programming model, allows the different technological capabilities of different regions, the production capabilities of each region, and the transportation costs of moving commodities between regions to be included. The solution of the linear program results in a set of commodity shipments within an economy which will result in the minimum cost of producing the designated commodity goals.[14]

The model presented by Mr. Harwitz will be discussed in

---

[14]Herbert Mohring and Mitchell Harwitz, Highway Benefits (Evanston: Northwestern University Press, 1962), pp. 91-131.

Chapter V. Chapter VI will recommend a cost-benefit method of analysis by which the time element, different sequences of investment projects, and a comparison of investment alternatives can be obtained through the use of the model.

CHAPTER V

INPUT-OUTPUT SYSTEMS AND MULTI-REGIONAL PROGRAMMING

An input-output and multi-regional programming method to relate the significant variables within an economy has been presented by Mitchell Harwitz in Highway Benefits. The linear program model relates production requirements, final demands, labor costs, regional production constraints, regional transportation constraints, and shipments of commodities within an economy and can be used to evaluate transportation projects within an underdeveloped country.

The notation developed by Harwitz is used throughout the following chapter. A capital letter is used to refer to a matrix. The capital letter, I, is used to represent an identity matrix. An underlined lower case letter is used to represent a row vector. A lower case letter is used to refer to a scalar.

Harwitz presented three different variations of a model which used multi-regional programming to minimize the cost of producing the commodities within an economy. The third variation is used in this paper because its use allows the determination of the mode of transportation for each shipment within the economy. The different modes of transportation which would generally be included in the model are shipments by road, rail, water, or air. The general nature of the linear program model is to minimize the total labor required to produce n commodities subject to constraints on final demands for each region, production capabilities within each region, a labor constraint, and constraints on the capacity for each mode of shipments within each region. The use of the model results in the determination of an efficient plan for production of the n commodities

while considering actual production costs and transportation costs.

The model considers two types of primary goods. Labor inputs are represented by $_i\underline{a}_o$, a row vector, containing the labor input required for each of the commodities produced in region i. The use of the subscript o, indicates that the input is labor hours. The second type of primary good is the different modes of transportation. The vector, $_{ij}\underline{v}_k$, is a 1 by n vector representing the cost of shipments in labor hours from region i to region j for the k^{th} mode of transportation for each of the n commodities. The labor inputs appear in the objective function and the transportation inputs appear in the constraints.

The shipments between regions and within regions are represented by a vector $^k_{ij}\underline{s}_n$, which is the shipment of the n^{th} commodity using the k^{th} mode of transportation from area i to area j.

The model was developed to consider the input requirements of intermediate commodities to produce a final commodity. The model contains n distinct commodities. The output of the n^{th} commodity is defined as x_n and the input of any other commodity, the m^{th}, in the production of commodity x_n as x_{mn}. The technical coefficient, a_{mn}, is defined as the ratio of x_{mn} to x_n. The technical coefficient specifies how much of an input commodity is required for the production of a final commodity. The technical coefficients are specified for each region and form a matrix, $_rA$, which is a n by n array of technical coefficients for the r^{th} region. This procedure realistically provides for differences in technology for different regions.

Final demands, programmed by the development plan, for the r^{th} region are given by a n by 1 vector $_r\underline{d}$. The total production requirement of the commodities, the n by 1 vector $\underline{x}$, is $x = A\underline{x} + \underline{d}$, the sum of the intermediate requirements for inputs plus the final demand for each of the n commodities. This constraint will appear in the final set of constraints in the form $(I - {}_rA)\ \underline{x} = {}_r\underline{d}$, where I is an identity matrix of size n by n.

The constraint to insure that the total labor supply is not exceeded is of the form $\underline{a}_0\ \underline{x} \leq L_0$, where $\underline{a}_0$ is the vector of labor inputs for the commodities and L_0 is the total available labor.

To insure that the capabity of a region to produce a commodity was not exceeded, constraints on the production capabilities of each region are included in the model. The n by 1 vector, $_r\underline{k}$, is a vector which includes a maximum production capability for the r^{th} region for each of the n commodities.

Transportation modes have a maximum capacity that can be shipped which is caused by limitations on the number of railway cars, boats, or aircraft which are available for use. To maintain a feasible solution which would not exceed the maximum capacity of any transportation mode, a constraint on the maximum capacity of each mode of travel for each area was included in the model. The vector, $_r\underline{t}$, is defined as the capacities of the k modes of transportation for the r^{th} region.

The linear program model for an economy containing 2 regions, n commodities, and 2 modes of transportation is shown in Figure 1,

Model of an Economy.[15] The size of the constraint matrix is dependent on the number of commodities, the number of regions, and the number of modes of transportation. If the number of regions is fixed at 2, the number of modes of transportation at 3, and the number of commodities at 2, the constraint matrix would be of dimensions 14 by 24. The size of the matrix increases rapidly as the number of commodities and regions are increased. The magnitude of the resulting linear program requires the use of computers to use it as an effective investigative tool.

The solution of the linear program defined by the model determines where production will occur, what shipments of commodities will result in the minimum labor cost, the regions which are operating at maximum capability, and the labor cost of producing the final goals at the minimum cost. All of the above information is required to efficiently plan the allocation of production and changes in the transportation network.

The dual of the linear program presented in Figure 1, Model of an Economy is to maximize the value of the final outputs of the economy less the costs associated with capacities in certain industries.[16] If an efficient means of production or shipment of a commodity is operated at maximum capacity, the industry concerned will be earning an excess profit because the final price of the commodity will be determined by the higher cost of the industry which is producing the remainder of the required output in a less efficient manner. The value of the final output minus the excess profits is the quantity that is maximized in the dual of the linear program presented in Figure 1. The dual is

---

[15] _Ibid._, p. 125

[16] _Ibid._, p. 120.

OBJECTIVE FUNCTION

$$\text{minimize } ({}_1\underline{a}_0,\ {}_1\underline{a}_0,\ {}_2\underline{a}_0,\ {}_2\underline{a}_0)\ \underline{s}$$

where;

${}_1\underline{a}_0$ is a (1 x n) row vector of labor input costs for the 1st region,

${}_2\underline{a}_0$ is a (1 x n) row vector of labor input costs for the 2nd region,

and

$\underline{s}$ is an (8n x1) column vector of shipments for each mode for each region for each commodity.

CONSTRAINTS

$$\begin{bmatrix} I-{}_1A & -{}_1A & I-{}_1A & -{}_1A & I & 0 & I & 0 \\ 0 & I & 0 & I & -{}_2A & I-{}_2A & -{}_2A & I-{}_2A \\ -I & -I & -I & -I & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -I & -I & -I & -I \\ -{}_{11}\underline{v}_1 & -{}_{12}\underline{v}_1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -{}_{11}\underline{v}_2 & -{}_{12}\underline{v}_2 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -{}_{21}\underline{v}_1 & -{}_{22}\underline{v}_1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -{}_{21}\underline{v}_2 & -{}_{22}\underline{v}_2 \end{bmatrix} \times \underline{s} \geq \begin{bmatrix} {}_1\underline{d} \\ {}_2\underline{d} \\ -{}_1\underline{k} \\ -{}_2\underline{k} \\ -{}_1\underline{t} \\ -{}_2\underline{t} \end{bmatrix}$$

where

I is a (n x n) identity matrix,

${}_1A$ and ${}_2A$ are (n x n)matrices of technological coefficients,

${}_{ij}\underline{v}_k$ are (1 x n) row vectors for the transporation costs for shipment from region i to region j using the k^{th} transportation mode for n commodities.

${}_i\underline{d}$, ${}_i\underline{k}$, and ${}_i\underline{t}$ are column vectors of the production goals, production capabilities, and transportation capabilities constraints for the i^{th} region.

FIGURE 1: MODEL OF AN ECONOMY

presented in Figure 2; Dual of the Model of an Economy.[17]

The model does have some limitations. The major limitation is that the equilibrium solution of the model is based on the assumption that the economy instantaneously adjusts to the new conditions which are used to test the effect of changes in production capability, technological capability, or the transportation network. In the actual economy, the results of the change would generally lag the actual change while the economy adjusted to the new conditions.

The model does not differentiate between commodities produced in different areas. This might be a serious limitation for use in developed economies but for underdeveloped economies the commodities which are considered critical will not generally require quality discrimination between commodities produced in different regions.[18]

The model does not include economies of scale returns for transportation network improvements.[19] It uses a price for a commodity transported by a mode of transportation without reference to benefits that will occur for producers which are using large scale transportation services. The model will tend to underestimate the benefits of improvements in the transportation network since it will not credit the economies of scale benefits that will occur in some instances. This can be corrected by identifying important economy of scale shipments and treating them as fixed inputs to the model rather than allowing the model to determine their size. This would

---

[17] Ibid., pp. 119-120.
[18] Ibid., p. 124.
[19] Ibid., p. 127.

OBJECTIVE FUNCTION

$$\text{maximize } (\underline{p}\ \underline{w}\ \underline{c}) \begin{bmatrix} {}_1\underline{d} \\ {}_2\underline{d} \\ -{}_1\underline{k} \\ -{}_2\underline{k} \\ -{}_1\underline{t} \\ -{}_2\underline{t} \end{bmatrix}$$

where;

$\underline{p}$ is a 1 by 2n row vector of final goods prices,
$\underline{w}$ is a 1 by 2n row vector of non-transportation capacity rents, and
$\underline{c}$ is a 1 by 2 row vector of transportation capacity rents.

CONSTRAINTS

subject to;

$$\begin{bmatrix} I-{}_1A & 0 & -I & 0 & -{}_{11}\underline{v}_1 & 0 \\ -{}_1A & I & -I & 0 & -{}_{12}\underline{v}_1 & 0 \\ I & -{}_2A & 0 & -I & 0 & -{}_{21}\underline{v}_2 \\ 0 & I-{}_2A & 0 & -I & 0 & -{}_{22}\underline{v}_2 \end{bmatrix} (\underline{p}\ \underline{w}\ \underline{c})' \geq \begin{bmatrix} {}_1\underline{a}_0 \\ {}_1\underline{a}_0 \\ {}_1\underline{a}_0 \\ {}_1\underline{a}_0 \end{bmatrix}$$

FIGURE 2: DUAL OF MODEL OF AN ECONOMY

require the calculation of their costs and would require that they be entered as input to the model.

An attempt to eliminate the limitations discussed above in a general manner would result in a model which could not be solved due to the existing limitations on the method of calculating the final solution. If a certain economy has characteristics which should be included in the model, these can be added by stipulating addional constraints to the linear program.

The model requires as input the technological coefficient matrices, production capabilities for each region, transportation costs and transportation capabilities for each of the modes of transportation, and the labor input costs. This minimum amount of information would be required for any method of economic evaluation.

The technological coefficient matrices are necessary for the evaluation of the original production goals which were specified by the development plan. In the same planning procedure, the production capability of each region was necessary to obtain reasonable estimates of the goals for the critical commodities.

The transportation costs for the commodities along each of the modes of transportation for each area can be measured. The initial input may have to be estimates but these can be refined each time the model is used. The transportation capabilities of the rail, water, and air facilities are pretty well defined by the numbers of railway cars, boats and aircraft which are available for use. The transportation capability of a road is difficult to measure but reasonable estimates can be obtained.

The dynamic nature of investment decisions has not been included in the model by Mr. Harwitz. The next chapter will discuss the use of the linear program model as part of a cost-benefit analysis that will include time in the evaluation of proposed investment projects.

CHAPTER VI

PROCEDURE FOR EVALUATING INVESTMENT PROJECTS

The model, discussed in the previous chapter, resulted in the minimum cost of producing the commodity goals at a single point in time. The procedure that is recommended in this chapter will use the model as a means of evaluating the benefits of investment projects. The resulting benefits will be used as input to a method of cost-benefit analysis.

The general procedure that is proposed is shown if Figure 3, Investment Evaluation Procedure. The first step is to obtain the production goals for the critical commodities, the discount rate, and the tentative budgets for technological change investments, production capability investments, and transportation network investments. It has been assumed that these parameters are inputs which are provided by the development plan.

The second step is to evaluate the existing situation using the model to obtain the optimum shipments that would occur with the parameters from the existing situation. The results of this evaluation would identify where the maximum production capability is being used, and where transportation capability constraints are active. This information can be used as an indication of areas where investments may be required. This would generate some of the projects for evaluation. The resulting solution of the model can be compared to the existing shipments that are occurring in the economy. This can be used to examine the ability of the model to describe the economy and to investigate reasons for discrepancies between shipments occurring and the optimum set of shipments that result from the solution of the model. This can be a result of incorrect parameters in the model,

STEP 1 Development plan establishes production goals for n critical commodities, the discount rate, and investment budget constraints for technological change, increased production capability, and changes in transportation network.

STEP 2 Model is used with the present parameters to determine which restraints are active; results indicate areas to be investigated for potential projects.

STEP 3 All proposed projects are evaluated to obtain the time streams of required investments, salvage values, and the expected changes in input parameters for the linear program

STEP 4 All project sequences are investigated as to feasibility for production goal requirements and budget restraints.

STEP 5 Model is used to develop minimum cost of producing commodity goals for all feasible sequences for 5, 10, and 20 year points in time.

STEP 6 Minimum investment sequence is identified.

STEP 7 Present value of benefits, investment expenditures, and salvage values is calculated for each investment sequence using the minimum investment sequence for comparison.

STEP 8 Ranking of investment sequences by economic evaluation is obtained.

STEP 9 Sensitivity of resulting ranking of sequences is investigated for changes in the investment budgets, discount rate, and production goals for the critical commodities. Steps 4 through 8 are repeated as necessary.

STEP 10 Sequences of feasible investments are evaluated for their ability to support noneconomic goals of development plan.

STEP 11 Final results of procedure are a feasible investment plan for 5, 10, and 20 year periods, recommendations for changes in the production goals of critical commodities, and recommendations for changes in the proposed budgets for technological, production and transportation investment sectors.

FIGURE 3: INVESTMENT EVALUATION PROCEDURE

lack of knowledge by decision makers controlling the economy, or factors which have not been included in the model. These discrepancies would be evaluated to insure that they do not result in improper use of the model.

The third step, the evaluation of each proposed investment project, requires the estimation of the time stream of costs for each investment project, the salvage value of each project at various points in time after its completion, and the changes the project will cause in the input parameters of the model. The technological improvement projects will require an engineering estimate of the technological coefficient matrix for the area where the project is to be implemented. An increased production capability project requires that an engineering estimate of the new production capability of the area be obtained. A transportation network project could result in the change in the cost vectors for shipments or in a change in the transportation capability constraint. All of the above changes in the input parameters of the model are primarily engineering estimate problems and do not require the evaluation of any types of benefits which cannot be substantiated.

The benefits from investment in a single project can be evaluated by introducing the changes in input parameters into the linear program and calculating the minimum cost to obtain the required commodity goals. The difference between the results obtained without the changed parameters and the new parameters caused by investment in the project would be the benefits of a single project. If the effects of all the projects were independent of other investments, this would permit the examination of different projects and a selection of the

optimal investment projects. Since the assumption that the effects of a single project is independent of all other investment projects is not valid, the model cannot be used in this manner to obtain a set of optimal investments. The value of the benefits that accrue to a single project are a function of the other investment projects and is affected by the sequence in which the other projects are initiated.

The fourth step, obtaining the possible sequences of investments, is initiated by evaluating the overall budget which has been allocated by the development plan for investments in the areas of technology, production, and transportation network changes. This requires the timestream of expected funds for investments be obtained for the evaluation period. It has been assumed for use in this chapter that the evaluation is based on a twenty year period with commodity production goals specified by the development plan for five, ten, and twenty year points in time. The appropriate time frames used by the underdeveloped country would be used in place of this arbitrary example of planning periods. The possible sequences of investments of the proposed projects can then be developed by investigating the time stream of costs for the projects under evaluation. By restraining a feasible sequence as one where the time stream of investments is less than or equal to the maximum investment funds available for each time period, a set of feasible projects can be found.

The set of sequences which are feasible for the restraint on investment funds can be reduced further by considering the required final outputs of the critical commodities. The first reduction in the number of feasible sequences can be found by eliminating any sequence where the sum of the final demands is greater than the sum of

the production capabilities of the areas. The next reduction can be accomplished by constructing a technological coefficient matrix which is composed of the minimum entry available within the existing economy and the proposed projects. The test to eliminate possible sequences would be to evaluate the sum of the final demands plus the sum of the intermediate demands for each of the commodities and compare this to the overall production capability of the country for each of the commodities. If this sum is greater than the 5 year, 10 year, or 20 year requirements, the sequence is not one which will provide a feasible solution to the production requirements.

The fifth step is to evaluate the linear program for each sequence which satisfied the investment and production restraints to obtain the minimum cost of producing the commodity goals for the 5th, 10th, and 20th years. Some of the sequences will be eliminated because the transportation capability constraints will be violated. This will result in eliminating additional sequences from further consideration. The final results of using the model will be a series of estimates of the minimum cost of producing the commodity goals for each feasible sequence for the 5th, 10th, and 20th year points in time. The model could be used to obtain an estimate for each year by inserting the changes created by the investments as each project is completed. It has been assumed in Figure 4: Feasible Sequences that these changes occur uniformly over the time frame so that an estimate for any year other than the points evaluated by the linear program can be found from the linear interpolation between the points evaluated. In Figure 4, four sequences have been indicated which will yield a feasible sequence which

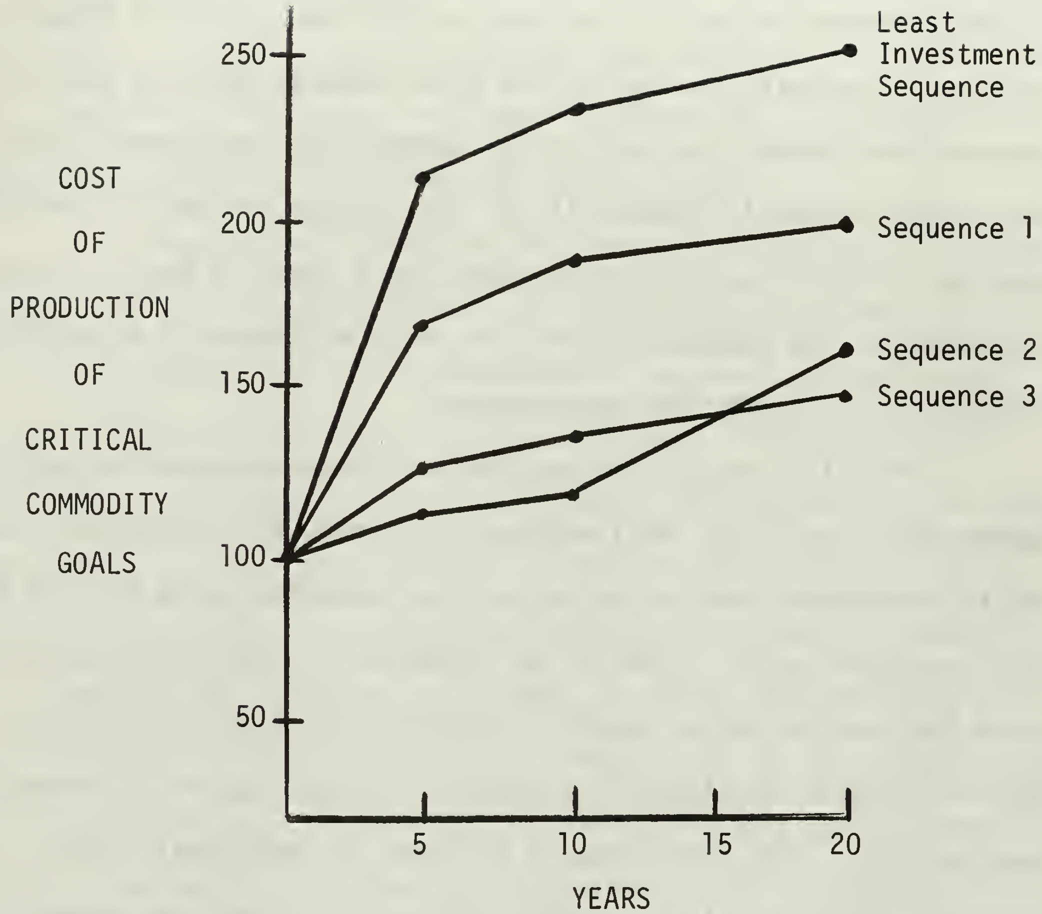

FIGURE 4: FEASIBLE SEQUENCES: Each sequence results from solution of linear program and meets constraints on investment funds, production goals, and production and transportation capabilities.

meets the requirements of the final commodity goals, for the investment constraint, and for the production and transportation constraints of the model.

The sequences labeled 1, 2, and 3 are the remaining feasible sequences which result from investments which are greater than the investments required for the least investment sequence but which do satisfy the constraint that they do not exceed the minimum funds available for investment in any one year. Each of the sequences has an associated time stream of required investments.

The benefit credited to an investment sequence is the difference between the cost of producing the n commodities for that sequence and the cost of producing the n commodities using the minimum investment sequence.

The different investment sequences will each have a salvage value at the end of the planning period. This must be considered when evaluating the total benefits achieved. The salvage value will be designated R_i, the residual salvage value of the i^{th} sequence at the end of the 20th year.

In comparing the benefits resulting from each of the sequences, the difference in investment time streams must be considered. The constraint for a feasible investment sequence required that the required investment funds be less than or equal to the available investment funds. A present value formulation would enable the differences in the time streams of the required investments, and the resulting benefits to be included in the evaluation of the overall benefits. The resulting formulation is;

$$PV_j = \sum_{i=1}^{20} \left[\left[({}_iC_L - {}_iC_j) - ({}_iI_j - {}_iI_L) \right] D^i \right] + (R_j - R_L)\, D^{20} \quad (1)$$

where

PV_j = the present value of the j^{th} sequence,

${}_iC_L$ = the cost of production for the least investment sequence in i^{th} year,

${}_iC_j$ = the cost of production for the j^{th} investment sequence in the i^{th} year,

${}_iI_L$ = the required investment for the least investment sequence in the i^{th} year,

${}_iI_j$ = the required investment for the j^{th} investment sequence in the i^{th} year,

D = the discount rate,

R_L = the salvage value of the least investment sequence at the end of the planning period, and

R_j = the salvage value of the j^{th} investment sequence at the end of the planning period.

The seventh step consists of using Equation (1) to evaluate the present value of sequences 1, 2, and 3. This procedure uses the least investment sequence as a means to obtain a consistent comparison between all other feasible sequences.

The eighth step is to order the feasible sequences according to their discounted present value.

The ninth step is to repeat the procedure contained in steps four through eight with plus and minus a percentage of the budgets for the three areas of investments. This is to enable the planners responsible for the development plan to obtain information on what would occur if the budgets for the three areas of investments were increased or decreased. Included in the procedure at

this point would be sensitivity analysis procedures which should be investigated. The rate of interest which is used in the discounting procedure should be evaluated at different levels to see how sensitive the final ranking of the sequences in the eighth step is to the discount rate which was obtained from the development plan. The production goals have been accepted as fixed input to the procedure from the development plan. The sensitivity of the resulting ordering in the eighth step should be examined for changes in the production goals.

The tenth step is to take the set of investment sequences obtained from the use of the model and evaluate these as to the noneconomic goals of the development plan. The eighth step in the procedure ranked the sequences according to the present value formulation. The largest present value resulting from a sequence indicates which sequence is the best sequence from an economic evaluation. In the evaluation of the noneconomic goals, a sequence other than the best sequence could be selected because it supports the noneconomic goals of the development plan better. The magnitude of the difference in the present value of the two sequences can be considered when the decision is made to select the sequence which will actually be implemented.

The final step indicated on Figure 3, is the resulting output of the entire procedure. A feasible investment plan for 5, 10, and 20 year periods is achieved. The use of this method also provides valuable feedback information for the development planning process. The model enables the feasibility of the production goals specified by the development plan to be checked against the ability of the allocated investment funds to result in a feasible solution. If the

linear program model will not result in a feasible solution for the output goals within the funds allocated to investments in technology, increased production, and transportation network improvements, the reasons for this can be identified. Either the production goals or the allocations of investment funds may have to be altered in the overall development plan.

The results of this method would be meaningful to the individuals who must make the final decisions concerning investments. This method provides a solution which can be explained in terms of lower production cost, lower transportation costs, and changes in technological improvements. The vector of transportation shipments enables the reason for the differences between various sequences to be investigated. The lower cost of a sequence can be traced to its source. The results of the method can be expressed in physical terms which can be understood by other than mathematicians. The importance of this was emphasized by Mr. Gerhard Colm and Mr. Theodore Geiger when they discussed "Country Programming As a Guide to Development."

> While the incorporation into the planning process of a highly technical complex of equations and calculations may delight econometricians, it may very well alienate the officials responsible for the approval and implementation of the plan. The intelligibility of the plan, especially in the underdeveloped countries, is more important for its political and popular acceptance than is its mathematical sophistication.[20]

All of the results of the proposed method can be traced back to their physical reason through the use of the shipments vector when the reasons for a particular sequence of investments resulting in a lower cost is explained.

---

[20] Robert E. Asher, et al., Development of the Emerging Countries (Washington: Brookings Institution, 1962), p. 63.

The method of evaluation can easily adjust to changes in the critical commodities, additional projects to be evaluated, changes in the production goals, or funds available for investment. The resulting changes merely require the insertion of the appropriate parameters in the linear program. When commodities are no longer critical, they can be easily eliminated from the model by removing them from the appropriate constraints.

Many underdeveloped countries must restrict their foreign exchange expenditures to a certain level. This restriction can be included in the recommended planning procedure by evaluating the time stream of costs for the projects in two parts, the foreign exchange requirements and the local exchange requirements. The process of evaluating the projects as to the ability to be funded within the budget restraints would have to meet an additional restraint on foreign exchange expenditures.

The procedure which has been recommended above would result in the identification of a sequence of projects which will result in a feasible investment policy which will achieve the production goals of the critical commodities. The process includes the evaluation of the projects from noneconomic requirements and enables whatever funding procedure is used within the underdeveloped country to see how much a deviation from the optimal economic sequence occurs when a sequence other than the optimal economic sequence is selected. If the proposed sequences for the expected budget and plus and minus a given percentage is provided as input to the funding procedure, the addition or subtraction of specific projects in the political process of funding can be based on economic analysis rather than on an

arbitrary percentage method of reducing the investment expenditures.

The final chapter will discuss the conclusions and recommendations for additional areas of study.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

The evaluation of investment projects within underdeveloped countries requires a procedure which allows the interactions between investments in different sectors to be considered. An evaluation of the investments in the transportation sector cannot be obtained without considering the investments programmed in technological improvements and increased production capability.

The procedure that has been recommended narrows the choice of investment opportunities to sequences which will yield a feasible solution to the budget constraints and critical commodity goals. The procedure will identify inconsistencies between the level of programmed investments and the required production goals.

The use of the least investment sequence in comparing the feasible investment sequences provides a consistent means of determining the benefits which will be credited to an investment sequence. The consideration of the projects as elements of a sequence eliminates crediting the same benefits to two or more projects.

The final results of the model can be presented in a manner which can be understood by the individuals involved in the development planning and political process of funding specific projects. The vector of actual shipments that would occur allows the effect of investment projects to be traced back to their origin.

The model is flexible, changes can be added or deleted with a minimum of effort and additional constraints can be included in the

linear program formulation.

The results of the linear program identify where production capability and transportation capacity constraints are active. This indicates potential areas for investigation of investment projects.

The procedure that has been recommended needs to be programmed for use with a computer. The number of possible sequences increases rapidly as the number of projects investigated is increased. Methods to obtain the feasible sequences meeting the production requirements while remaining within the proposed budget for investment expenditures should be developed so that the number of possible sequences that must be investigated with the linear program are kept at a minimum level.

Estimates of road capacities have been proposed by several different authors. This area still requires a considerable amount of examination to provide an accurate method of evaluating a road's capacity.

The use of the procedure that has been recommended will result in a feasible solution to the investment requirements of an underdeveloped country. The economic evaluation of the investment proposals will enable the final funding procedure to consider the economic cost of not implementing the optimal investment sequence. The procedure results in a rational method of investigating investment opportunities and provides a consistent means of evaluating the benefits of investment projects.

BIBLIOGRAPHY

Asher, Robert E., et al. Development of the Emerging Countries. Washington: Brookings Institution, 1962.

Baumol, William J., Economic Theory and Operations Analysis. Englewood Cliffs, New Jersey:Prentice- Hall, Inc., 1961.

Beckman, Martin, C.B. McGuire, and Christopher B. Winsten, Studies In The Economics of Transportation. New Haven: Yale University Press, 1955.

Carstens, R.L., and L.H. Csanyi. "Economic Analyses for Highway Improvements in Underdeveloped Countries." Iowa State University Bulletin, Engineering Report No. 44, Vol LXIII, Nov. 4, 1964.

Chenery, Hollis B., and Paul G. Clark. Interindustry Economics. New York: John Wiley and Sons, Inc., 1964.

Dorfman, Robert. Measuring Benefits of Government Investments. Washington: Brookings Institution, 1963.

Eckstein, Otto. Water-Resource Development. Cambridge, Massachusetts: Harvard University Press, 1965.

Foster, C.D. The Transport Problem. London: Blackie and Son Limited, 1963.

Krause, Walter. Economic Development. San Francisco: Wadsworth Publishing Company, Inc., 1961.

Mohring, Herbert, and Mitchell Harwitz. Highway Benefits. Evanston, Illinois: Northwestern University Press, 1962.

Perloff, Harvey S., et al. Regions, Resources, and Economic Growth. Baltimore: The Johns Hopkins Press, 1960.

Shaner, Willis W. "Economic Evaluation of Investments In Agricultural Penetration Roads In Developing Countries." Stanford: Stanford University, 1966.

Taaffe, Edward J., Richard L. Morrill and Peter R. Gould. "Transport Expansion in Underdeveloped Countries: A Comparative Analysis," Geographic Review, LIII, No. 4, (October, 1963), pp. 503-529.

Tinbergen, Jan, and Hendricus C. Bos. Mathematical Models of Economic Growth. New York: McGraw-Hill Book Company, Inc., 1962.

Winch, David M. The Economics of Highway Planning. Toronto: University of Toronto Press, 1963.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	20
2.	Library Naval Postgraduate School Monterey, California	2
3.	Director, Systems Analysis Division (OP 96) Office of the Chief of Naval Operations Washington, D.C. 20350	1
4.	Prof Ronald Kochems (Thesis Advisor) Department of Operations Analysis Naval Postgraduate School, Monterey, California	1 1
5.	Major Gerald A. Vick, USA 96 South Street Red Bank, New Jersey 07701	1

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Naval Postgraduate School	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

A Method To Evaluate Investment Projects in Underdeveloped Countries

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Thesis

5. AUTHOR(S) *(Last name, first name, initial)*

Vick, Gerald A., Major, United States Army

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1968	52	

8a. CONTRACT OR GRANT NO. b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. AVAILABILITY/LIMITATION NOTICES

This document is subect to special export controls and each transmittal to foreign nationals may be made only with prior approval of the Naval Postgraduate School.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Postgraduate School Monterey, California

13. ABSTRACT

The evaluation of proposed projects for changes in the transportation networks of underdeveloped countries is examined by using a benefit-cost method of analysis. The benefits of investment projects are evaluated through the use of a linear program model which minimizes the cost of production for critical commodity goals. The constraints for the linear program are obtained through the use of input-output systems and multi-regional programming. A present value formulation is used to compare the results of a least investment sequence to all other feasible sequences. The use of the procedure recommended results in the identification of a feasible investment sequence which will result in the achievement of the required production goals. The results of the procedure can be explained in physical terms to identify the reasons for the differences in the resulting present value of the various investment sequences.

DD FORM 1 JAN 64 1473

UNCLASSIFIED

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Underdeveloped Countries						
Road Networks						
Benefit-Cost Analysis						
Investments						

[redacted]